INSTRUCTION MANUAL

kepco inc.®

131-38 SANFORD AVENUE • FLUSHING 52, N. Y.
Area Code 212 IN 1-7000 • TWX # NY 4-5196

INSTRUCTION MANUAL

VOLTAGE REGULATED POWER SUPPLY

MODEL SC 18-2M

SERIAL NO. . . . . .

kepco inc. 131-38 SANFORD AVENUE • FLUSHING 52, N. Y. • Area Code 212 IN 1-7000 • TWX # NY 4-5196

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SECTION A. SPECIFICATIONS AND DESCRIPTION

A-1. ELECTRICAL AND PHYSICAL SPECIFICATIONS.

....DC OUTPUT VOLTAGE:
0-18 volts, continuously variable.

....DC OUTPUT CURRENT:
0-2 amperes, continuous duty.

....AC INPUT:
105-125 volts, 50-65 cps; 1.3 amperes maximum, at 125 v ac, 60 cps.

....REGULATION -

- LINE: Less than 0.1% for 105 to 125 v line voltage change, at any output voltage setting in the specified range.

- LOAD: Less than 0.1%, or 0.003 v whichever is greater, for 0 to 2 amperes load change, at any output voltage setting in the specified range.

....RECOVERY TIME:
50 microseconds. Defined as the time required for the output voltage to return to within 0.1 v of the output voltage setting.

....OUTPUT IMPEDANCE:
Less than 0.01 ohm from DC to 1 KC.
Less than 0.1 ohm from 1 KC to 100 KC.

....RIPPLE:
Less than 0.001 volt, rms.

....STABILITY:
Output voltage drift less than 0.1% or 0.006 v whichever is greater, at constant ambient temperature over a period of 8 hours after the supply has reached equilibrium. Drift is less than 0.5% during warm-up following a "cold" start, (approximately 3/4 hour) before supply reaches equilibrium.

....AMBIENT OPERATING TEMPERATURE:
-20 C to +50 C.

....TEMPERATURE COEFFICIENT:
Output voltage changes Less than 0.05% per degree C change.

....METERS:
Furnished on units with suffix "M" following Model No.
Voltmeter 0-20 volts, 2-1/2".
Ammeter 0-2 amperes, 2-1/2".

....STORAGE TEMPERATURE:
-40 C to +85 C.

....DIMENSIONS:
Height 4-1/4"; Width 8-5/32"; Depth 13-5/8".

....COLOR:
Kepco Standard Gray Hammertone.

....SHIPPING WEIGHT:
27 pounds, approximate.

A-2. TERMINALS AND CONTROLS -

- ON FRONT PANEL.

....POWER ON-OFF SWITCH and PILOT LIGHT.

....INPUT POWER FUSE.

....DC OUTPUT AND GROUND TERMINALS. Binding posts, clearly marked. The output terminals are isolated from the chassis, either Positive or Negative terminal may be grounded. Note: The chassis is connected to the third, or ground pin (green wire) of the power line-cord.

....VOLTAGE CONTROL. One-turn continuously variable, for setting the output voltage.

- ON REAR PANEL.

....BARRIER TERMINAL STRIP. Barrier type terminal strip with nine screw terminals provides additional connection to the DC Output and Ground, and connecting terminals for Remote Error Sensing, Remote Voltage Control and Current Regulated Operation. (See "Special Features" Section A-3, and Section C, of this Manual)

....CURRENT LIMIT CONTROL. Screwdriver adjustment accessible through labelled opening provided on rear panel, for setting the value to which the output current will be limited. (See "Special Features" Section A-3)

A-3. SPECIAL FEATURES

....OVER-TEMPERATURE PROTECTION. In the event an over-temperature condition develops, a thermostat relay turns the DC Output off. (The fan motor will continue operating). The relay is reset and DC Output restored, after the unit has cooled, by turning the Power Switch off, and then on.

....OVERLOAD PROTECTION. The maximum output current is automatically limited to a factory pre-set amount equal to 120% of the maximum rated output current of the supply. This allows operation into a sustained overload up to full short-circuit. Output voltage restores when the overload is removed.

....CURRENT LIMIT ADJUSTMENT. An adjustable output current limiting control is provided, separate from the factory set maximum current feature. The limiting circuit may be adjusted with this control to automatically limit the output current to any value from 10to 120% of the maximum rated output of the supply. (See Section C)

....REMOTE ERROR SENSING. Terminals are provided for sensing the regulated output voltage directly at the load, by-passing, and thus eliminating the effect on regulation, of any voltage drop in the connecting leads between the output terminals and the load. (See Section C)

....REMOTE VOLTAGE CONTROL. Terminals are provided for the connection of an external Voltage Control in place of the internal Control, for remote control adjustment of the output voltage. The ratio of Control resistance to the voltage that is to be controlled remotely, is 1000 ohms per volt above zero; e.g., for remote control 0-18 volts, Control resistance required=0-18 K. (See Section C)

....CONSTANT CURRENT OUTPUT. This supply may be adapted to provide Regulated Current output, by connecting two resistors externally to terminals provided, and without requiring internal modification to the unit. (See Section C)

DC Output Characteristics, Regulated Current Operation.
Current: 0.01 ampere to maximum rated output.
Voltage: 0 to maximum rated output (volts).
Regulation: Line, 0.1% for 105-125 line voltage change.
Load, 0.2% for minimum to maximum load change.

SECTION B.

THEORY OF OPERATION

This power supply is of a servo or closed loop design in which the pass elements are in series with the load. (See block diagram B-1).

The voltage drops in the closed loop system are automatically adjusted according to the comparison of a sample output voltage with the reference voltage in the CONTROL UNIT. The differential product of this comparison is amplified and fed back as the ERROR INPUT to control the voltage drop across the pass transistors. The ERROR INPUT to the PASS CIRCUITRY is a negative or degenerative feedback signal. Consequently, the voltage drop across the pass transistors is such as to oppose output voltage change.

CAPITALIZED TERMS ADOPTED FOR FOLLOWING OUTLINE AND DISCUSSION REFER TO DESIGNATIONS ON THE CIRCUIT SCHEMATICS IN THE REFERENCE INDEX.

.....1. POWER UNIT (Circuit Schematic Tile)

A. INPUT CONTROL CIRCUITRY - Controls power input from the line to the DC SOURCES.

B. DC SOURCES - Provide main and auxiliary rectified power for all DC circuitry.

C. PASS CIRCUITRY - In the MAIN DC path to the output. All current drawn by the load goes through the pass elements, hence the name.

.....II. CONTROL UNIT (Circuit Schematic Tile)

A. REFERENCE VOLTAGE CIRCUITRY - Maintains a stable voltage standard for the comparison circuitry.

B. THE COMPARISON AMPLIFIER - Functions as the "error sensing" and cascade amplification circuit.

.....III. COMPARISON BRIDGE -

Consists of elements in both the POWER UNIT and CONTROL UNIT in a circuit configuration which effects a comparison between an output voltage sample and a stable reference voltage.

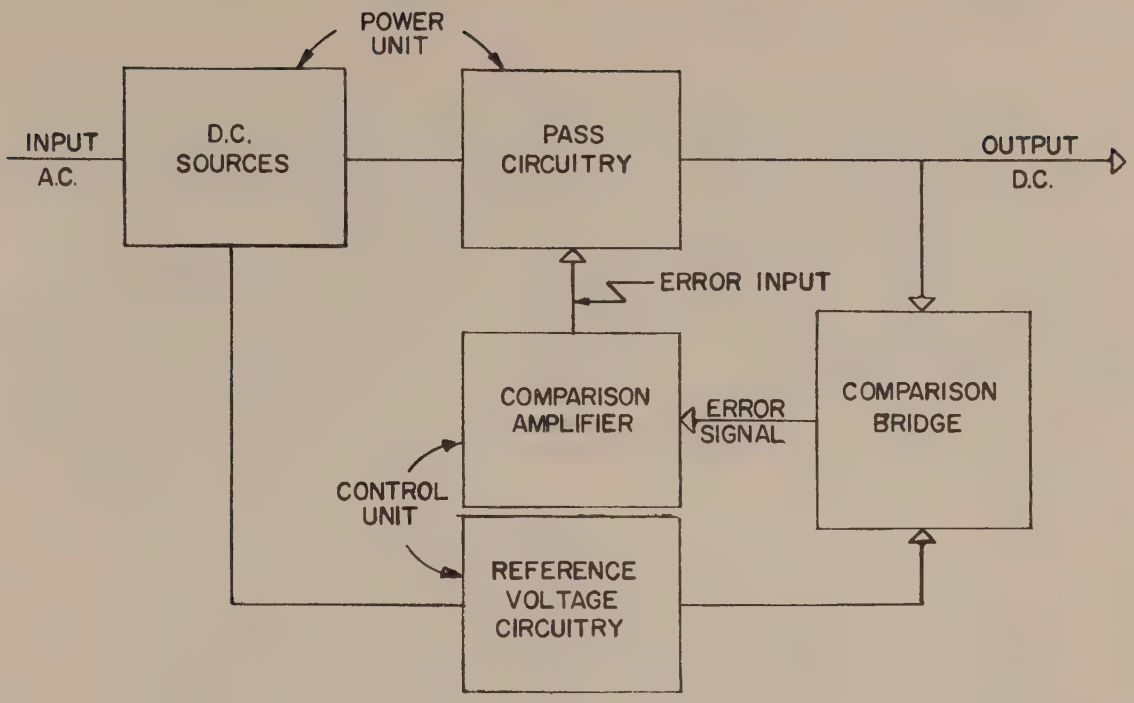


DIAGRAM B-1

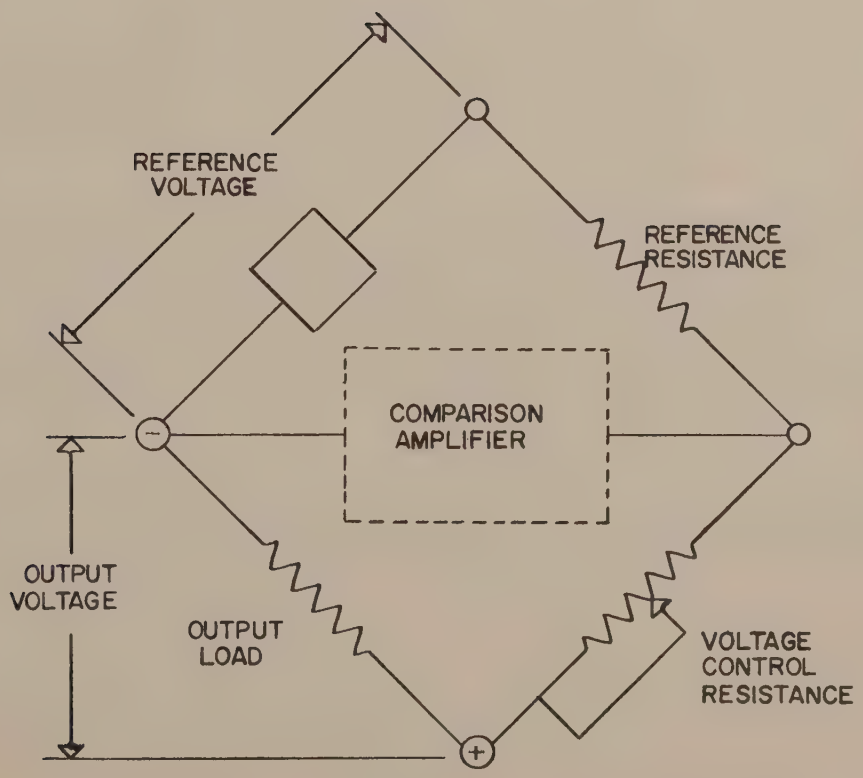


DIAGRAM B-2

NOTE:

The following discussion describes the elements of the foregoing outline in greater detail. As before, capitalized terms refer to designations on the schematic diagrams. Some of this discussion is of a general nature and may not apply in every detail to this specific model. Variations in the basic outline occur primarily in connection with the PASS CIRCUITRY INPUT CONTROL CIRCUITRY or the REFERENCE VOLTAGE CIRCUITRY and reflect design considerations relevant to the particular output requirements of the model. It should not be assumed that a set of circuit schematics is incomplete because it does not include all of the reference nomenclature used in this discussion.

.....I. POWER UNIT

A. INPUT CONTROL CIRCUIT:

(1) With the input switch closed, a forward bias on one semiconductor diode in the ENERGIZING CIRCUIT will draw a charging current for the capacitor which energizes the INPUT RELAY coil closing the input to the DC SOURCES transformers. As soon as the INPUT RELAY is closed, the DC in the input control circuit circulates through the thermal relay and input relay coil, bypassing the charged capacitor and holding the relay closed.

(2) If the pass element containing the thermostat control becomes overheated, the thermal switch opens the DC path to the INPUT RELAY de-energizing the relay coil and cutting off the input to the DC SOURCES.

NOTE:

The AC line power must be interrupted in order to reset the input relay after the thermal switch has opened the input to the DC SOURCES. Once the capacitor in the ENERGIZING CIRCUIT is charged, it cannot hold the relay when the thermal switch opens. This action tends to prevent damage to the pass elements from overheating in case the transistor associated with the thermostat dissipates heat faster than the other pass elements.

(3) When the input relay is opened by the action of the thermal switch or by pulling the line cord, the DISCHARGE RESISTOR effectively shorts the MAIN FILTER CAPACITOR preventing overvoltage surges.

B. DC SOURCES:

(1) RETURN SUPPLY (full wave rectified and filtered) - provides a return path for leakage current (I_{CO}) from the pass transistors.

It is also a bleed path which provides a minimum operating current for the emitters of the pass transistors, enabling them to continue to remain operative or "sensitive" to the ERROR INPUT when the load current becomes zero or vanishingly small.

(2) MAIN SUPPLY (full wave rectified and filtered) - provides MAIN DC for the output, subject to the regulatory action of the PASS CIRCUITRY. The MAIN DC path includes the pass elements and the load in series.

(3) I_{CO} SUPPLY (full wave rectified) - Provides a supply of current to prevent spurious biasing of the pass transistors by collector leakage current (I_{CO}). I_{CO} generated as a function of temperature and flowing oppositely to the emitter base current tends to alter the ERROR INPUT unless this compensating supply provides bias stabilization.

(4) COLLECTOR SUPPLIES (negative half-cycle rectified) - provide proper collector bias for the PRE-DRIVERS.

C. PASS CIRCUITRY:

The power transistors which function as pass elements may be regarded as electronic variable resistors (or variable conductors) controlled or "varied" by an amplified ERROR INPUT. The amount of current "passed" by these transistors is a function of the magnitude of the forward conducting emitter-base bias. Since the ERROR INPUT is applied to the base terminal, a negative input will aid the forward conducting bias of a PNP transistor while a positive input will reduce the forward conducting bias. In response to the polarity and magnitude of the ERROR INPUT, the pass transistors control the current and voltage distribution in the MAIN DC loop and effect a constant output voltage.

Two main classifications of pass transistors may be indicated on the schematic acoording to the way in which they are driven:

(1) DRIVEN PASS - "driven" by the ERROR INPUT from the CONTROL UNIT. A DRIVER and a PRE-DRIVER may be connected in cascade with the DRIVEN PASS. These amplification stages increase the response and sensitivity of the system to cutput voltage changes. The DRIVEN PASS may be a single series pass transistor

or a series pass group of transistors connected in parallel for increased current capacity.

(2) SLAVE PASS - found in transistorized units requiring more than one series pass group in the MAIN DC path. These pass transistors "slavishly" follow the response of the DRIVEN PASS to the ERROR INPUT. The SLAVE PASSES are driven through a SLAVE VOLTAGE DIVIDER which effects an approximately equal voltage division among the series pass groups in models where the voltage range requires more than one group of series pass elements. The SLAVE PASSES may or may not have preliminary amplification stages in cascade.

When series pass groups contain transistors connected in parallel, an EQUALIZING RESISTOR is associated with each transistor. These EQUALIZING RESISTORS, tied to each emitter, provide a means of compensation for intrinsic differences among transistors within a pass group.

The expression "drop voltage" is sometimes used to describe the amount of voltage drop required of the pass elements to bring the COMPARISON BRIDGE into balance. This is the difference between the input and the desired output. True balance or stability is inherently impossible in a servo system, but the unbalance may be reduced to as small a magnitude as desired in a dynamically corrective system.

.....II. CONTROL UNIT

A. REFERENCE VOLTAGE CIRCUITRY:

The function of the REFERENCE VOLTAGE CIRCUITRY is to maintain a precise, stable voltage for the COMPARISON BRIDGE. This is normally achieved according to the model CONTROL UNIT with either of two basic design approaches:

(1) A CASCADE ZENER REFERENCE, consisting of Zener diodes of succesively decreasing values in cascaded stages each of which produce an increasingly regulated reference voltage. In practice, usually only two stages are used so that in effect the first Zener diode is a regulator for a voltage reference diode.

(2) Balanced amplifier regulation - Any disparity between the bases of the transistors in the set of 1st BALANCED AMPLIFIERS is coupled to the set of 2nd BALANCED AMPLIFIERS. The 2nd BALANCED AMPLIFIERS couple this amplified "error signal" to a REFERENCE DRIVER and a REFERENCE PASS which regulate the current through a REFERENCE DIODE in a manner analogous to the action of the PASS CIRCUITRY in the POWER UNIT.

B. COMPARISON AMPLIFIER CIRCUITRY:

(1) The COMPARISON AMPLIFIER consists of a series of cascaded transistor amplifiers which boost the "error input" to a sufficient level to drive the PASS CIRCUITRY in the POWER UNIT.

(2) The COMPARISON AMPLIFIER is connected across the COMPARISON BRIDGE from the junction of the VOLTAGE CONTROL and the REFERENCE RESISTANCE to the junction of the Zener reference diode and the negative output terminal. (See Diagram B-2). This arrangement is similar to that of the null galvanometer across a Wheatstone bridge. The unbalance in the COMPARISON BRIDGE is detected and amplified by the COMPARISON AMPLIFIER CIRCUITRY beginning a chain of circuit responses which produce an ERROR INPUT signal of proper phase and magnitude to effect corrective action by the pass circuitry.

.....III. Comparison Bridge:

(1) This bridge circuit implements the comparison between the OUTPUT VOLTAGE and the REFERENCE VOLTAGE. The signal produced by the comparison drives the COMPARISON AMPLIFIER CIRCUITRY.

(2) The Comparison Bridge is represented schematically in Diagram B-2.

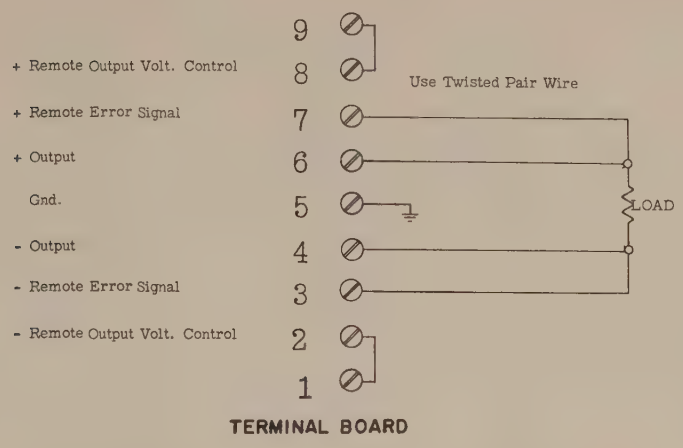
(3) Balance occurs in the Comparison Bridge when the following ratios are equal:

$$\frac{\text{Output Voltage}}{\text{Voltage Control Resistance}} = \frac{\text{Reference Voltage}}{\text{Reference Resistance}}$$

(4) When the Comparison Bridge is unbalanced by a decreasing output voltage drop across the load, it gives rise to a negative bias at the base of the COMPARISON FOLLOWER in the COMPARISON AMPLIFIER CIRCUITRY. This signal, amplified, acting as the ERROR INPUT negatively biases the base of the DRIVEN PASS, aiding its forward conducting bias and increasing the output voltage.

(5) A bridge unbalance caused by an increasing output voltage produces, of course, a chain of oppositely biased circuit responses which reduce the voltage across the load.

CONVERTING TO REMOTE ERROR SENSING



PROCEDURE:

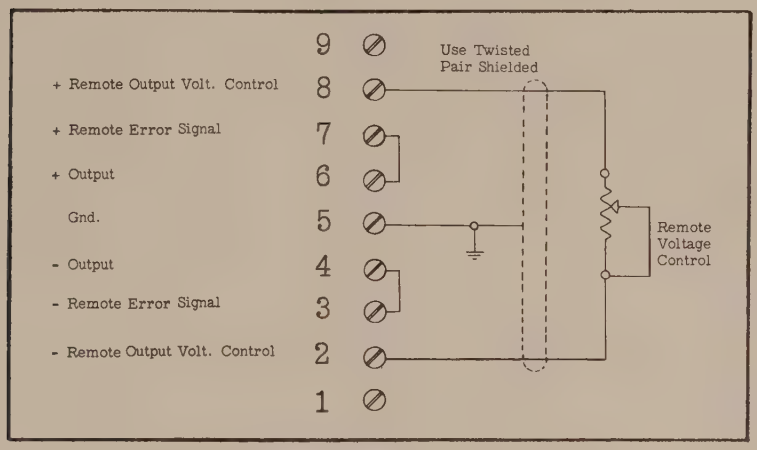
1. With AC input disconnected, remove jumper between POSITIVE OUTPUT and POSITIVE REMOTE ERROR SIGNAL (terminals 6 and 7) between NEGATIVE OUTPUT and NEGATIVE REMOTE ERROR SIGNAL (terminals 4 and 3) on rear terminal strip.

2. Using twisted pair wire, connect sensing leads from POSITIVE REMOTE ERROR SIGNAL (terminal 7) and from NEGATIVE REMOTE SIGNAL (terminal 3) to the load, observing polarities.

3. Using twisted pair wire, connect load supply leads from POSITIVE OUTPUT (terminal 6) and NEGATIVE OUTPUT (terminal 4) to the load.

NOTE: In operations requiring remote error sensing, voltage drops across the load supply leads will change the effective setting of the maximum current adjustment and possibly worsen regulation. By setting the MAXIMUM CURRENT ADJUST on the CONTROL UNIT it is possible to compensate for this effect for up to a maximum drop of 1/2 volt across the negative load supply lead. The 1/2 volt limit is imposed by the fact that this drop reduces the maximum forward conducting bias on the series pass transistors. The input base bias to the pass transistor is limited by the factory setting of the MAXIMUM CURRENT ADJUST. Consequently to avoid a deterioration in the ability of the pass transistors to follow the ERROR SIGNAL feedback and correct the output voltage, the following steps should be taken:

1. Turn CURRENT LIMIT ADJUST (if provided) to maximum clockwise position.
2. Load the power supply with the remote resistance necessary to draw slightly more than 120% of the maximum rated supply current at the indicated supply output voltage.
3. Turn MAXIMUM CURRENT ADJUST clockwise until output current reaches 120% of maximum rating.



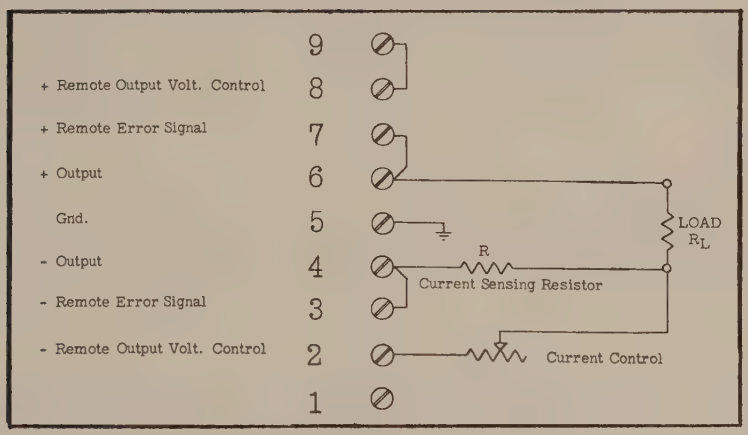
TERMINAL BOARD

PROCEDURE:

1. The REMOTE VOLTAGE CONTROL resistance, fixed or variable, should be equal to the product of the desired output voltage and the ohms per volt ratio specified for this model. (See discussion on REMOTE OUTPUT VOLTAGE CONTROL terminals in Section A).

2. With AC power disconnected, remove jumper between POSITIVE REMOTE OUTPUT VOLTAGE CONTROL (terminal 8) and terminal 9, and jumper between NEGATIVE REMOTE OUTPUT VOLTAGE CONTROL (terminal 2) and terminal 1.

3. Connect shielded twisted pair wire leads from POSITIVE REMOTE OUTPUT VOLTAGE CONTROL (terminal 8), and from NEGATIVE REMOTE OUTPUT VOLTAGE CONTROL (terminal 2) to REMOTE VOLTAGE CONTROL resistance. REMOTE VOLTAGE CONTROL, if variable, should be connected so that clockwise rotation increases resistance.



TERMINAL BOARD

PROCEDURE:

1. Remove jumper between NEGATIVE REMOTE OUTPUT VOLTAGE CONTROL (terminal 2) and terminal 1.

2. Connect a CURRENT CONTROL resistor from the NEGATIVE REMOTE OUTPUT VOLTAGE CONTROL (terminal 2) to the load as shown in the above diagram. The CURRENT CONTROL resistance should be numerically equal to (in ohms) or greater than the ohms/volt ratio specified for this unit in the discussion on REMOTE OUTPUT VOLTAGE CONTROL terminals in Section A. (e.g. for a 330 ohms/volt model use a 500 ohm pot.).

3. Choose a CURRENT SENSING resistance sufficient to produce a 1 volt drop at maximum desired output current. Connect this CURRENT SENSING resistor in series with the external load R_L and the NEGATIVE OUTPUT (terminal 4).

   Current Sensing Res. = 1 / max. output amps. desired

SECTION D MAINTENANCE AND REPAIRS

....GENERAL.

The components of this Power Supply are conservatively rated and have been tested and selected to provide long and trouble-free operation.

However, if component failure should occur, it is recommended that trouble-shooting be handled by personnel familiar with transistor circuitry, preferably with experience in feedback regulator design. Exceptional component accessibility provided by resistor board construction and plug-in sub-assemblies, facilitates servicing should it be required.

....MAINTENANCE.

Under normal operating conditions the only maintenance that will be required will consist in lubricating the fan motor every six months.

....FACTORY REPAIRS.

If it becomes necessary or desirable to return the equipment to the manufacturer for repair, it should not be shipped to the factory without having prior authorization and shipping instructions. The inclusion of detailed information with the unit, or in correspondence prior to its return will greatly expedite the completion of repairs and return of the equipment to the sender. In any correspondence to the factory about this Power Supply, the model and serial numbers should always be included.

....GENERAL TROUBLESHOOTING INFORMATION.

In servicing this equipment it should be remembered that the essential regulating circuitry is a closed loop DC servo system. The same circuit sensitivity which enables a high degree of regulation to be obtained also increases the susceptibility of the circuit components to interrelated functional disorders if the equipment is improperly serviced.

....REFERENCE MATERIAL.

The Instruction Manual furnished with the Power Supply is identified with the serial number of the unit, assuring that the information contained in it is correct and up to date for the unit to which it applies. The following reference material contained in the Manual should serve as an aid in trouble-shooting:

1. Schematic diagrams showing essential voltage measurements, and component values.
2. Parts location photos and drawings.
3. Parts lists identifying all replacement parts with schematic number, description and specifications and (a typical) manufacturer's part number.

....PRELIMINARY CHECKS.

1. Before proceeding with systematic trouble-shooting it is advisable to carefully examine the Supply for any mechanical disorders: broken leads, loose plugs, loose fuses, foreign matter, etc.

2. If the malfunction relates to an over-temperature condition, determine if the fan is operating properly and whether the ventilation openings were not blocked during operation.

3. Locate and check all internal as well as external fuses.

4. Determine whether any internal adjustments such as "Reference Current Adjust" (RP Control) or current limiting adjustments, have not been left in an alternate setting following a special application set-up.

5. In units that contain a variable transformer in addition to a potentiometer for voltage control, check the security and indexing of the shaft coupling between the two.

....MECHANICAL ASSEMBLIES.

1. Control Unit. The Control Unit ("TRAM") is a plug in sub-assembly that is held in place on the main chassis by screws and either brackets or stand-offs.

2. "Pass" Transistor Assemblies. The power transistors used in the "Pass" circuit are mounted on individual "heat sink" assemblies, called "Stats". Each Stat assembly plugs into a socket on the main chassis, and is held in place by insulated screws. These screws are accessible from the underside of the chassis, and must be removed in order to unplug a Stat.

CAUTION:
The metal heat-sink frames of the Stats are at collector voltage potential, which is the negative side of the output from the DC rectifier. Suitable precaution should be observed if the unit is turned ON while the cover panels are not in place.

NOTES ON TRANSISTOR SERVICING TECHNIQUES.

....MECHANICAL.

1. A transistor should not be disconnected from, or connected to its circuit while voltage is still present in the circuit.

2. When a soldering iron must be used to remove or install a transistor, or a diode, the heat of the iron while it is being applied to the terminals will almost certainly damage the device unless precautions are taken to prevent it:
   a. When soldering, always apply a temporary "heat sink" to the leads between the iron and the semiconductor to drain off the heat travelling up the lead. Note: Pliers are often used for this purpose - be sure they are effective; e.g., flat blade "duck-bills" are good, narrow blade or "toothed" long-nose pliers may be poor.
   b. Solder quickly, so as to limit the application of heat to the briefest possible duration. In this respect use a good iron with proper and sufficient heat for the connection. An iron of too low heat tends to require longer application.

3. When removing or installing a transistor or a diode which has its case connected to one of its elements, be sure to preserve the arrangement of any insulating materials, such as washers or bushings.

4. When installing plug-in transistors which have flexible leads, be sure to align the leads and socket pins properly; especially in the "universal" sockets which were designed to accommodate more than one lead pattern.

....ELECTRICAL.

1. Transistor checking instruments, either commercial types or those of local design, may be used. These are usually effective and practical, but not in every case, depending on many circumstances including the accessibility of the unit under test, and the range of the instrument.

2. In-Circuit analysis. In some cases the condition of a transistor may be determined by observing certain of its electrical characteristics while it is operating in the circuit. This may range from voltage readings to AC analysis with an oscilloscope.

3. Ohmeter check. Transistor failures of a more complete nature such as shorted or open junctions may be easily detected by test with an ohmeter. However, some precautions are necessary:

....ELECTRICAL. (continued)

a. Use the low ohms scale only (Rx1), and then only if the source voltage of the meter (battery) is not more than 2 volts. The use of a higher range or one with high battery voltage may give erroneous indications and may even damage a transistor.

b. The "common" or black terminal on most ohmeter instruments is the Positive terminal of the ohmeter battery, not negative as is commonly believed. When checking semiconductors with an ohmeter it is usually necessary to know the polarity of this voltage in order to interpret the readings obtained. Some manufacturers of ohmeters are now indicating this polarity on their meters.

c. An ohmeter test between any two terminals of a transistor indicates by the needle deflection whether it is conducting ohmeter current between those two terminals, and the amount of deflection is related to the amount of this current and to the voltage drop developed across the junction. The actual reading in ohms is not as significant as are other conclusions from the readings. With the polarity of the meter applied as a forward bias to either the base-emitter or base-collector junction, forward current should flow with the needle deflecting in the order of 5-50 ohms; with the polarity reversed in both cases only leakage current flows with little or no perceptible deflection. In either case the apparent ratio between readings of opposite applied polarity should be in the order of at least 100 to 1. A reading between emitter and collector should be high in both directions.

d. When an ohmeter is used to test a transistor that is still in the circuit, the effects of other components in the circuit should be taken into consideration.

4. Substitution. The above procedures are very often used to localize a trouble down to a circuit area or one component with final proof dependent on substituting a known good component. It is possible for one bad transistor in a circuit to "pull" another one with it. When a transistor is found to be defective, it should not be replaced before all others have been checked, including those which would appear to be not directly associated with the defective one.

.... DIODES.

1. Most of the preceeding material on transistors is applicable to diodes, except that they are two terminal devices consisting of a single junction. The ratio of "front to back" readings on an ohmeter should similarly be in the order of 100 to 1.

2. When replacing diodes, be sure to observe the proper polarity:
   a. The "triangle" of a diode symbol represents the anode and "points" in the direction of forward conduction under conditions of applied forward bias.
   b. Diodes are marked with their polarity in terms of their output and the cathode is marked positive (+).
   c. Zener diodes may be checked with an ohmeter provided they are of the single junction type. Double anode types have a common cathode which is not brought out to a terminal. Thus, whichever polarity of the ohmeter is applied to the two anode terminals, it will read a high resistance reverse bias in both directions. A short however, can be detected. Manufacturers are not yet consistent in their marking of polarity on Zeners; before disconnecting a Zener, be sure to note its markings with respect to the terminals to which it is connected.
   d. A positive test of a Zener diode is to measure the voltage across it while it is in operation, and if instrumentation is available, the voltage regulation across its terminals should be measured and compared to its ratings.

REGULATION AND ITS MEASUREMENT

.... DEFINITIONS.

Line Regulation stated in percentage of the output voltage specifies the maximum amount that the output voltage will change as the result of a specified change in line voltage, with the load maintained at a constant value.

Load Regulation stated in percentage of the output voltage (or in actual value) specifies the maximum amount that the output voltage will change as the result of a specified change in output load current, with the line voltage maintained at a constant value.

.... ERROR SENSING.

In a feedback controlled Series Regulating Power Supply the voltage which is to be regulated or held constant, is continuously "sampled" and fed back into the Supply for comparison with the internal reference voltage. The input for this voltage is the external "Error Signal" terminals on the rear of the supply, and the supply will act to regulate whatever output voltage is fed back to these terminals. Assuming that it is the voltage across the output terminals which is to be regulated, this voltage is applied to the "Error Signal" terminals by means of jumpers or links installed between the Error Signal and adjacent output terminals. Connected in this manner, the voltage at the rear output terminals receives optimum regulation; any voltage drops in the load current path beyond these terminals will not be regulated.

The point then at which optimum regulation appears may be considered as an ideal DC voltage source (disregarding the output impedance of the supply). Any resistance appearing between this source and the load will cause a voltage drop that will degrade the regulation obtained at the load.

As an example, consider a 32 volt 5 ampere Supply with 0.01% regulation. At maximum output voltage, a change in load from 0 to 5 amperes will result in only a 3.2 mv or less change in regulated output voltage at the terminals. If the load were connected by only 12 inches of #12 A.W.G. wire, in each lead, the total drop in the resistance of the leads would be 16 mv, 5 times the equivalent regulation.

A means of overcoming this is provided of course, by connecting up for "Remote Error Sensing"(see Section C). The Error Signal jumpers are removed, and these terminals are connected directly to the remote load terminals by separate leads. This enables the supply to provide optimum regulation directly to the voltage across the load, by-passing any effects of resistance in the load leads.

....ERROR SENSING. (continued)

Up to 500 mv in the load connecting leads may be compensated for effectively by use of Remote Error Sensing. The purpose of these examples is to illustrate that great care must be exercised when setting up the output connections, in order to preserve the desired degree of regulation especially when proceeding to measure the regulation.

....MEASURING REGULATION OF THE SUPPLY.

The regulation may be measured at any point in a particular set-up, and the results obtained evaluated on the basis of any external factors in the set-up which may affect the regulation. However, if it is desired to verify the regulation performance of the Power Supply itself, it should be measured without the presence of any of these factors which are external to the Supply and which may influence the results obtained.

....PROCEDURE.

1. The Error Sensing jumpers should be in place, and both the load and the measuring device should be connected to either the rear or the front output terminals.

2. Avoid measuring at the front terminals while the load is connected at the rear, as the load current will produce a voltage drop (however small) in the internal buss connecting the front terminals to the rear terminals.

3. It is recommended that the connection of both the load and the instrument be made to each output terminal with a single length of #14 buss looped around the terminal, as in Fig. D-1.

....INSTRUMENTATION.

1. Line Voltage. By definition, load regulation is specified for a condition of constant line voltage. A regulated AC source is required, which should be adjustable if line regulation is also to be measured. (Kepco Model 920B Line Voltage Stepper)

2. Load. A suitable variable load is required.

3. Measurement. Any instrument may be used which is capable of measuring both the absolute value of the output voltage and the small magnitude of change in the output voltage as the line or load changes are applied, for example:

....INSTRUMENTATION. (continued)

3. a. A differential voltmeter may be used; or a Kepco Model 901C Regulation Analyzer which will provide measurements directly in percentage values.
   b. A DC coupled oscilloscope may be used if a suitable auxiliary DC voltage is available to "buck-out" the DC voltage under test. The buck-out voltage must be at least equal in magnitude to and have a greater order of regulation than the voltage under test.

....RIPPLE MEASUREMENT.

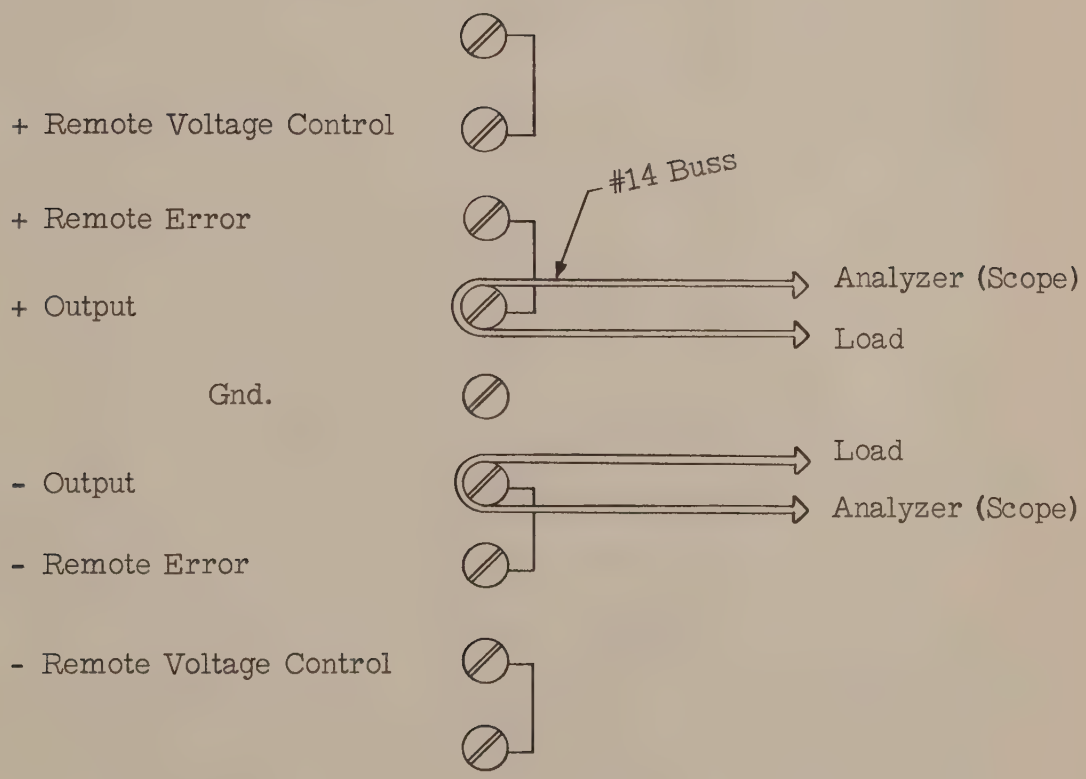
Any AC ripple component present in the DC output of a properly functioning Power Supply will be small in magnitude, on the order of millivolts. It is usually stated in the specifications for the Supply either in millivolts RMS or in percentage (in RMS) of the output voltage. Because of its small magnitude, a sensitive instrument must be used to measure the ripple, and care must be exercised in order to obtain accurate readings.

1. Be certain that the input to the measuring instrument contains a blocking capacitor to isolate the ripple component from the DC voltage, and that the DC voltage rating of the capacitor is sufficiently high for the DC output voltage that will be applied.

2. Some rectifier types of AC meters do not contain a DC blocking capacitor, and DC current will pass through the rectifier to the meter movement. In such cases, or where the internal capacitor does not have a high enough DC rating, a 0.1 μf capacitor (with sufficiently high DCWV) connected in series with the high side of the input will isolate the DC from the ripple.

3. Interconnecting leads between the Power Supply and the instrument should be short and preferably shielded to prevent stray AC pickup. When using a measuring instrument that is connected to the same power line, be certain to have good connections in the interconnecting leads to avoid the introduction of a ground loop.

CONNECTIONS FOR REGULATION MEASUREMENT



SECTION E

CONTROL ADJUSTMENTS

.....OUTPUT VOLTAGE CONTROL:

The output voltage of this supply may be varied continuously through its specified range by means of an adjustable OUTPUT VOLTAGE CONTROL.

.....CURRENT LIMIT ADJUST: (Designated CL on schematics)

The maximum safe current capacity of this supply is 120% of the rated supply. An automatic current limiting device in the Control Unit limits the pass current whenever the output current exceeds this value.

To accommodate special operation requirements, the screwdriver adjustment, called "CURRENT LIMIT ADJUST", is available on the Control Unit. The current limit can be thus manually set at any value in the range from 0 to 120% of the rated current supply.

NOTE: Current limiting adjustments available on this model are specified in Section A under "Protective Features".

FOR EXAMPLE: If it is desired to limit the output current to a maximum of 0.2 ampere, the procedure is as follows:

(1) Load the supply to at least 0.25 ampere.

NOTE: As the current limit is approached the supply regulation becomes slightly poorer. Consequently, for best regulation throughout the operating load current range, the current limit adjust should be set 25% higher than the maximum desired

output current.

(2) Turn the CURRENT LIMIT ADJUST control counter-clockwise until the output current reduces to 0.2 ampere.

In the above example the load regulation of the power supply will be within specification from 0 to 0.16 ampere.

.....MAXIMUM CURRENT ADJUST: (Designated MC on schematics)

Like the CURRENT LIMIT ADJUST, this limiter is part of the Comparison Amplifier circuitry in the Control Unit. The potentiometer associated with this control serves to establish a maximum safe current limit for the power supply. It is PRE-SET at the factory at a value equal to 120% of the maximum rated output current. When the output current tends to exceed this pre-set limit, the Pass Transistor biasing is automatically adjusted to reduce the pass current.

THE MAXIMUM CURRENT ADJUST SETTING SHOULD NOT BE CHANGED UNLESS IT IS REQUIRED FOR REMOTE ERROR SENSING OPERATION. (SEE IMMEDIATELY BELOW.)

.....MAXIMUM CURRENT ADJUSTMENT FOR OPERATION WITH REMOTE ERROR SENSING:

Unless the current limiters are adjusted for operation with remote error sensing the current supplied to the load will be limited to a value less than 120% of rated supply by the amount of voltage drop in the lead connections.

To avoid this limiting action, the following steps should be taken:

(1) Load the supply with a remotely connected resistor which will draw slightly more than 120% of the rated supply current at the indicated supply voltage.

(2) Turn the CURRENT LIMIT ADJUST to its maximum clockwise position.

(3) Turn the MAXIMUM CURRENT ADJUST clockwise until the output current is exactly 120% of the rated supply current.

(4) Turn the CURRENT LIMIT ADJUST counter-clockwise to limit the output current to any desired amount from 0 to 120% of maximum rated supply.

.....RP CONTROL ADJUSTMENT:

Some control units contain a locking type screwdriver adjustment designated "RP ADJUST". In converting to REMOTE OUTPUT VOLTAGE CONTROL OPERATION it may be necessary to adjust the ohms/volt ratio to the value specified in SECTION A under REMOTE OUTPUT VOLTAGE CONTROL. With the unit set up for remote output control, loosen the locking nut and turn the RP potentiometer under the proper ohms/volt between the remote voltage control resistance and the output voltage is obtained. (e.g. in a 1,000 ohms/volt unit a remote voltage control resistance of 18,000 ohms obtains an 18 volt output.)

Be sure to tighten the locking nut after this adjustment has been made.

PARTS LIST

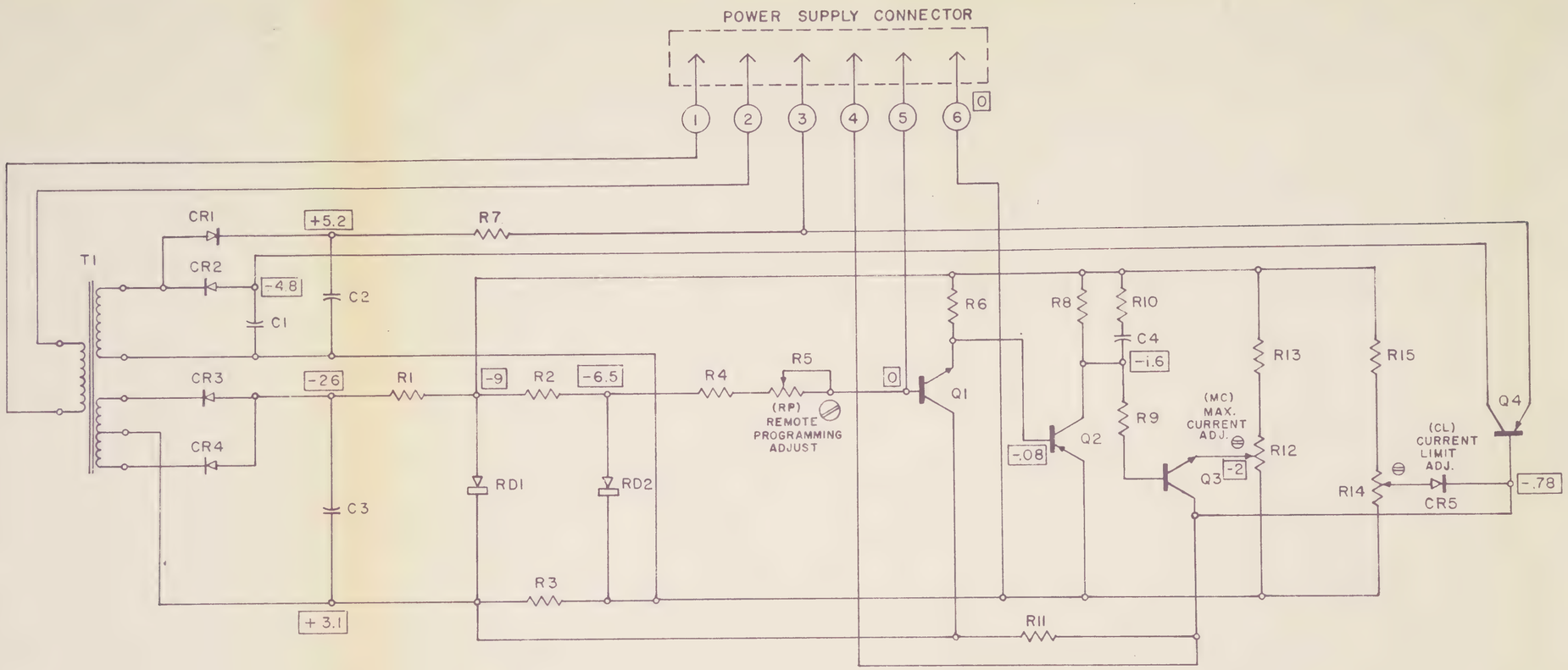
DRAWING S-TRAM-2-01

C1	- 500	MF	12 WV
C2	- 100	MF	12 WV
C3	- 100	MF	50 WV
C4	- 0.02	MF	200 WV
CR1 thru CR5	- 1N91 Diode		
Q1	- GT-1092 Transistor		
Q2	- 2N382 Transistor		
Q3	- 2N35 Transistor		
Q4	- 2N382 Transistor		
R1	- 680	Ohm	1 watt
R2	- 1	K	1/2 watt
R3	- 220	Ohm	1/2 watt
R4	- 4.7	K	1/2 watt
R5	- 5	K	2 watt Pot.
R6	- 10	K	1/2 watt
R7	- 430	Ohm	1/2 watt
R8	- 4.7	K	1/2 watt
R9	- 4.7	K	1/2 watt
R10	- 220	Ohm	1/2 watt
R11	- 4.7	K	1/2 watt
R12	- 500	Ohm	1.5 watt WW Pot.
R13	- 680	Ohm	1/2 watt
R14	- 2.5	K	1.5 watt WW Pot.
R15	- 2.7	K	1/2 watt
RD1	- SV13 Reference Diode		
RD2	- SV7 Reference Diode		
T1	- Kepco #100-1026		

PARTS LIST - MODEL SC-18-2
MODEL SC-18-2M*

DRAWING S-SC-18-2-02

B101	- Fan		
C101	- 1000	MF	50 WV
C102	- 2500	MF	30 WV
C103	- 1000	MF	50 WV
C104	- 0.1	MF	500 WV
C105	- 50	MF	150 WV
C106	- Omitted		
C107	- 100	MF	25 WV
C108	- 0.05	MF	600 WV
C109	- 0.22	MF	200 WV
CR101 and CR102	- Silicon Rectifier PT-5		
CR103	- Germanium Rectifier 1N91		
CR104 and CR105	- Silicon Rectifier TM-21		
F101	- 2 Amp. Fuse		
*M101	- Meter, 0-2 A DC		
*M102	- Meter, 0-20 V DC		
PL101	- Neon Pilot Light NE-51		
Q901 thru Q905	- 2N441-4 Transistor		
R101 and R102	- 500	Ohm	20 watt WW
R103	- 1	K	2 watt
R104	- 20	K	2 watt Pot.
R105	- 5.6	Ohm	1 watt
R106	- 1	K	2 watt
R107	- Omitted		
R108	- 68	Ohm	1 watt
R109	- 120	Ohm	2 watt
R901 thru R904	- 1.5	Ohm	3 watt WW
RL101	- DPDT Relay		
S101	- DPDT Switch		
S102	- Thermoswitch N. O.		
T101	- Kepco #100-1027		
TB101	- Jones #9-140-Y		



NOTE:
ALL VOLTAGES TAKEN UNDER CONDITIONS SPECIFIED ON MAIN SCHEMATIC.

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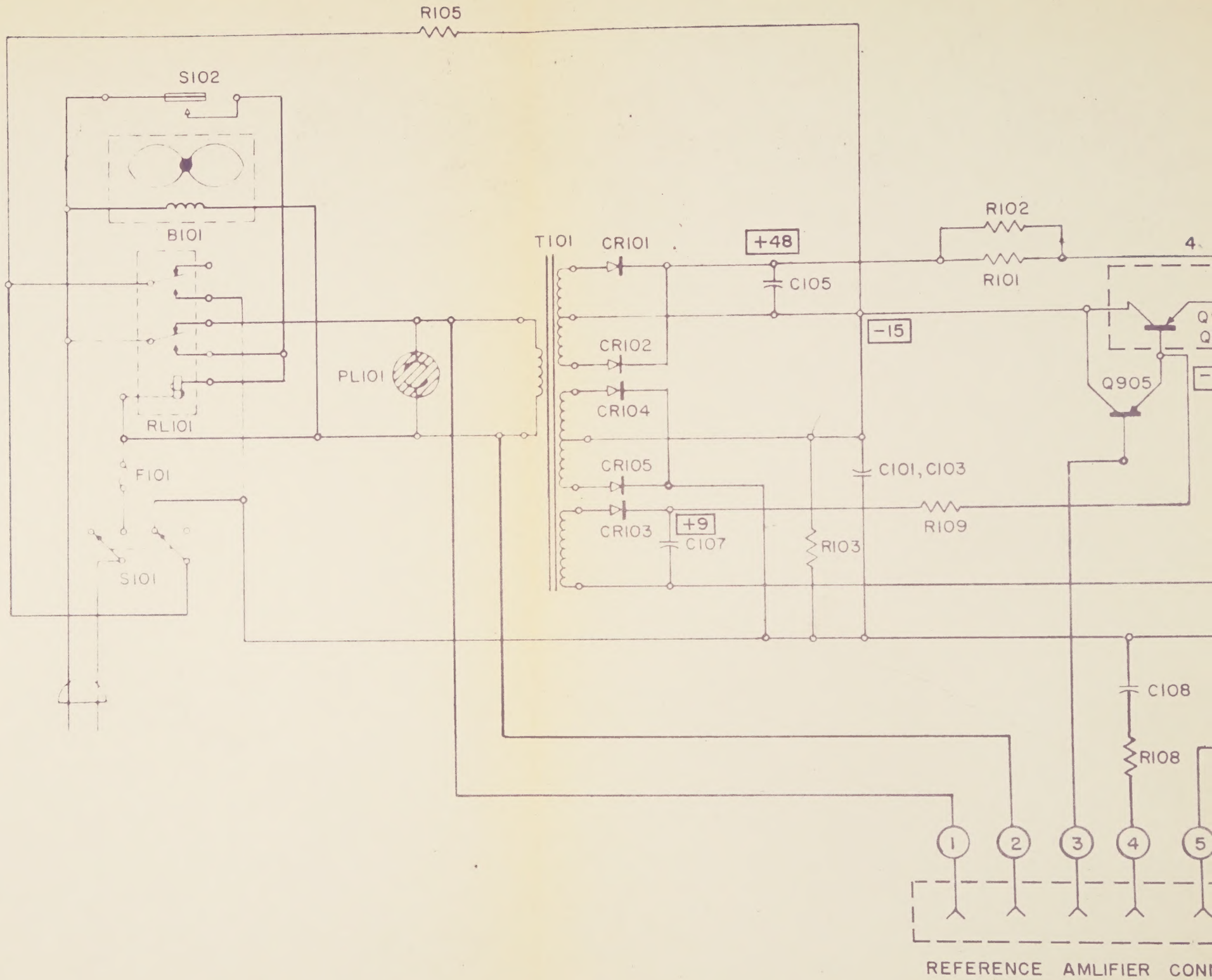
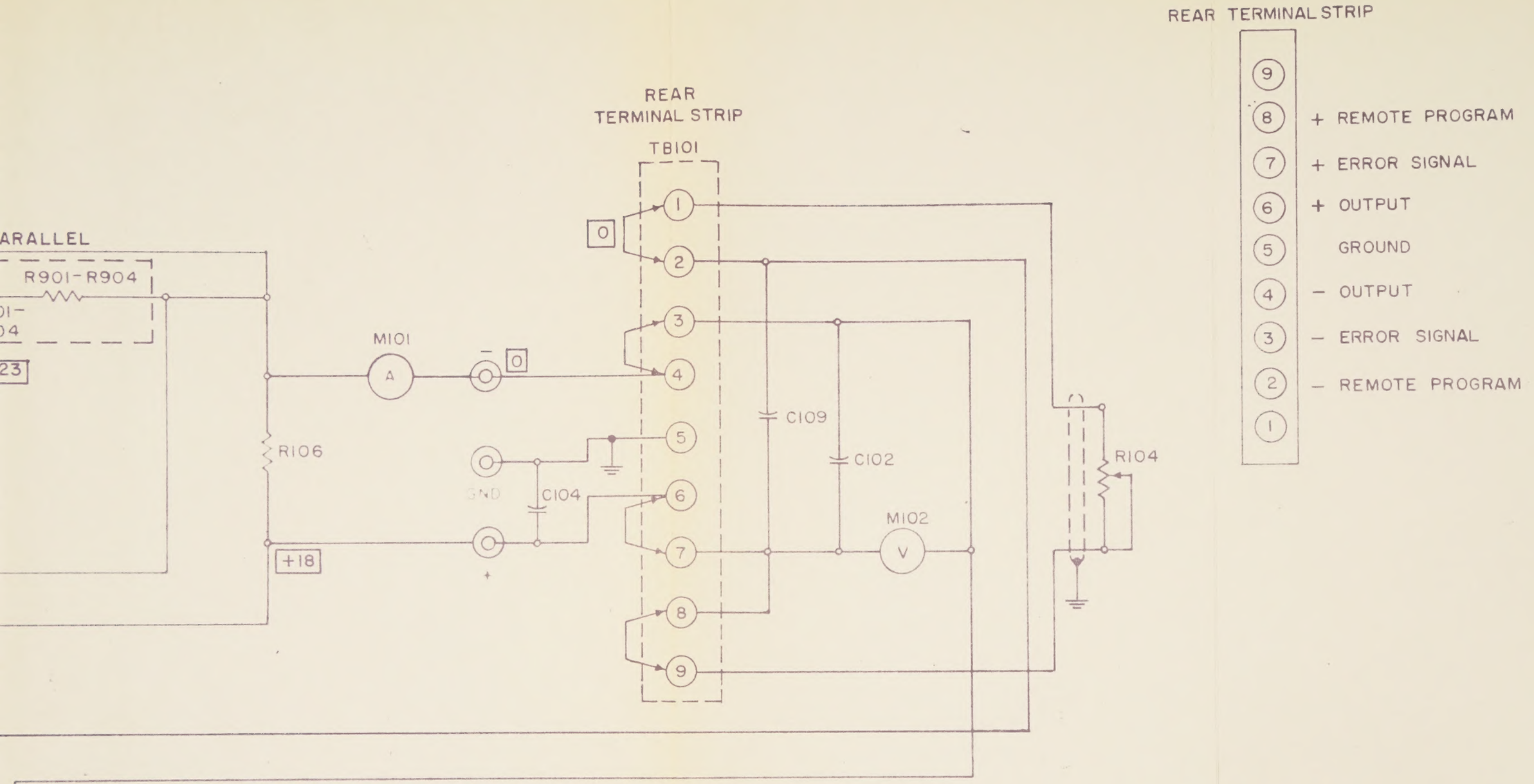
ITEM: REFERENCE AMPLIFIER	DES A.A.R
MODEL TRAM-2	APPD K.K 9.8.5
DWG. No S-TRAM-2-01	DFTM W.S.
	CHKD J.R.G.


R105
S102
B101
RL101
F101
S101
PL101
T101
CR101
CR102
CR104
CR105
CR103
+48
C105
+9
C107
-15
R102
R101
Q905
C101, C103
R109
R103
C108
R108
1
2
3
4
5
REFERENCE AMLIFIER CONN



NOTE: M101, M102 IN SC-18-2M ONLY.
ALL VOLTAGES TAKEN UNDER FOLLOWING CONDITIONS
1- AC INPUT = 115V 60~
2- NO LOAD WITH OUTPUT VOLTAGE SET TO MAXIMUM RATED VALUE.
3- VOLTAGES MEASURED AT 20,000Ω/VOLT WITH RESPECT TO NEGATIVE OUTPUT TERMINAL, UNLESS OTHERWISE NOTED.
4- ALL OUTPUT JUMPERS IN PLACE AS SHOWN.

KEPCO LABORATORIES
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ITEM POWER SUPPLY	DES.
	APPD 5-1-58
MODEL SC-18-2	DFTM W.S.
DWG. No. S-SC-18-2-02	CHKD

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